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ABSTRACT

This document is one of five learning packets on alternative energy developed as part of the descriptive curriculum research project in Arkansas (see note). The overall objectives of the learning packets are to improve the level of instruction in the alternative energies by vocational exploration teachers, and to facilitate the integration of new content on energy into existing vocational programs. Each learning packet contains unit objectives, information, transparency masters, lecture outline, suggested activities, student assignment sheets, tests, and answers to the tests. This unit on alcohol fuels covers the following topics: introduction to alcohol fuels; process for making ethanol alcohol for fuel; and modifying an automobile engine to use ethanol. A glossary is also provided. (KC)

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ALCOHOL FUELS

INSTRUCTIONAL MATERIALS

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USE OF THIS PUBLICATION

The overall objective of this publication is to improve the level of instruction in the alternative energies by vocational exploration teachers.

The development of alternative sources of energy and the increasing demand for energy conservation require that vocational educators develop new curriculum and improve existing delivery systems. All vocational education instructors must begin to acquire a minimum background in alternative energy sources and must be prepared to respond in a positive way to the energy education needs within their areas of specialization. It is anticipated that the use of this prepared learning package will facilitate the integration of new content on energy into existing vocational programs.

INSTRUCTIONAL UNIT

This packet contains objectives, information, transparency masters, lecture outline, suggested activities, student assignment sheets, tests and answers to the tests. These materials have been printed on colored paper to code their use. The following key will help easily identify each use by color:

White - teacher instructional materials

Green - information materials, teacher and student use

Yellow - student assignment materials

Golden - tests, teacher controlled

Pink - answers to tests and assignments, teacher use only

One set of each is included in the learning packet. The teacher should reproduce enough of the student use materials to adequately furnish his class with the proper materials.

Objectives

Included in the packet are measurable objectives. These objectives state the goals of the unit of study in such a way that both teacher and student will know what performance is expected.

Information Sheets

Each unit of instruction has information sheets which contain essential facts for that unit. These sheets are coded green and are intended for both teacher and student use. If inadequate information is contained in the student textbook, the teacher may reproduce these sheets for student use.

Instructional Materials

Instructional materials included with the unit contain transparency masters, suggested teaching activities, a lecture outline and a bibliography. These sheets are white and intended for teacher use. Each teacher is encouraged to consider these materials as a starting point and to develop additional activities and teaching materials to meet specific needs.

Student Assignment Sheets

Assignment sheets are included to give students an opportunity to apply knowledge and skill acquired through reading assignments, lecture and practice. These sheets are yellow and may be reproduced for student use.

Tests

A test is included in each unit to enable the teacher to measure student achievement. These sheets are golden and should be reproduced only for testing purposes.

Answers

Answers to student assignments and tests follow each assignment or test. These are coded pink and should be restricted to teacher use only.

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UNIT OBJECTIVES

- To work and experiment with energy systems in order to gain an understanding of energy sources, conversion, transmission, storage and control.
- To provide an opportunity in which students can gain career information for entry into energy-related occupations.
- To develop problem-solving and creative techniques in working with energy systems.

SPECIFIC OBJECTIVES

- The student will demonstrate at an accuracy of 75 percent or above, his ability to answer the content questions on the written test provided with the unit.
- The student will demonstrate at an accuracy of 75 percent or above, his ability to relate the procedures for fermentation of alcohol fuels.
- The student will demonstrate at an accuracy of 75 percent or above, his ability to relate the procedure for the distillation of alcohol fuels.
- The student will be able to name eight modifications necessary for an internal combustion engine designed for gasoline to run on alcohol.

OUTLINE

I. INTRODUCTION

II. PROCESS FOR MAKING ETHANOL ALCOHOL FOR FUEL

- A. Mash Preparation
- B. Hydrolysis-Saccharification
- C. Fermentation
- D. Distillation

III. MODIFYING AN AUTOMOBILE ENGINE TO USE ETHANOL

IV. GLOSSARY

INTRODUCTION

The problem of gasoline shortages has caused long lines at many gas stations. In many portions of the country, people are putting off trips because of the lack of fuel or the prohibitive price of fuel. This problem will not go away. It may even get worse.

Does this mean Americans must give up their cars? No, say scientists. Cars that use other kinds of fuel can be built.. One of these possible fuels is alcohol. Alcohol is a liquid that burns much like gasoline. In some ways it's better than gasoline.

Gasoline is made from oil. And there's only so much oil in the ground. Someday it will be all used up. But alcohol is made from plants. So as long as there are plants, people can make alcohol.

Brazil has already decided to switch from gas to alcohol. Brazil's scientists have made some cars with special engines. These run on alcohol. And they have run so well that Brazil's leaders want all trucks, cars, and busses to have alcohol engines by 1990.

In Brazil 750 government cars are already running on alcohol. Also the automobile manufacturers say that alcohol has proved to be an even better fuel than gasoline. Engines run better on it, they say. They contend that alcohol engines don't make the air as dirty as gasoline engines do.

Could alcohol be used to power cars in the United States? U.S. scientists think so. In fact, some U.S. gas stations already sell gas mixed with a little alcohol- about one gallon of alcohol for every 10 gallons of gas.

Some U.S. automakers are already building engines that could use only alcohol.

Alcohol is a fuel that is definitely in our future. It is to further the understanding of this alternate fuel that we dedicate this section of the Alternative Energy Curriculum.

The following is a reprint from "Arkansas Energy Future-Alcohol." This material is used with the permission of the Arkansas Department of Energy.

PROCESS FOR MAKING ETHANOL ALCOHOL FOR FUEL

When an individual decides to investigate making alcohol fuel, one of the first things that must be done is to determine what raw material will be used to make alcohol. It is possible to make alcohol from almost any organic material. Three types of organic material generally used to make alcohol are sugars, starch, and cellulose. All of these fall into the category of carbohydrates. Due to economic factors, abundant supply and relatively simple processing procedures, starch has been used as a feed stock for making alcohol fuel. For this reason, we will examine the process for converting starch to alcohol.

There are many so-called starch crops that can be used to make alcohol. Examples of starch crops are corn, potatoes, barley, grain sorghum, wheat, rice and oats. Examples of crops that can be grown in Arkansas and their yield of 197 proof alcohol are given in Table 1. (next page)

TABLE I

Alcohol Yields From Various Crops

MATERIAL	Gallons/Tons	Gallons/ Bushels
Corn	96.4	2.7
Wheat	86.6	2.6
Barley	68.3	2.5
Potatoes	37.0	1.11
Oats	63.0	1.05
Sugar Beets	22.1	.72
Rice	79.5	2.3
Grain Sorghum	79.5	2.6
Sorghum Cane	70.4	2.6

Mash Preparation

Preprocessing or grinding the chosen raw material is necessary to ready the material for efficient processing. This makes the starch in the raw material more accessible to water, heat and enzyme actions that must take place while processing it into alcohol. Grinding the material into flour is not necessary; however, obtaining a material that approaches that of corn meal is desirable. A hammer mill similiar to the ones found on many farms is sufficient to grind the raw material to the extent desired.

The alcohol processing equipment should be kept as clean as possible

in order to aid in the prevention of unwanted bacteria cultures in the mash mixture. These bacteria cultures can be harmful to the hydrolysis and fermentation processes. By raising the temperature of the mash to 250 degrees F. for 20 minutes, under 15 lbs.of pressure, the mash mixture will be sterilized. This will gelatinize the starch molecules and allow enzymes or acid greater access to the bonds holding the molecules together. Further, the proteins will become insoluble and will, therefore, be easier to separate from the mash and will provide better nutrition when fed to animals.

For each bushel of corn used, between 15 and 20 gallons of water should be added. This is less than the total amount needed for fermentation (27 to 28 gallons), but will require less energy for the cooking process. Then, additional water can be added to the hot mixture to cool it to the proper temperature for fermentation, when that step is begun.

Merely boiling the mash will not sterilize it and will require more energy than pressure cooking. A simple rule to follow is to make the starchy material soft. This can be accomplished by boiling the mash for thirty minutes or pressure cooking the mash at 250 degrees F. and 15 lbs.of pressure for 20 minutes or 360 degrees F. and 160 lbs.of pressure for 30 seconds. The rule to remember is the hotter, the faster. The cooking process will break the starch granule down and expose the bonds holding it together.

Hydrolysis - Saccharification

Before cooking, the acid concentration in the mash should be adjusted to obtain a pH of between 6.0 and 6.5. If the mixture is base, the acid concentration can be adjusted by adding sulphuric or hydrochloric acid in dilute form.

The pH level in the mixture can be determined by the use of pH test paper. This is a filter paper impregnated with certain dyes that change color as the acid concentration changes. Be careful to dilute the acid before putting it into the mash mixture and only use a little at a time.

Approximately .3 ounces of alpha amylase enzyme can be added for each 100 pounds of corn in the mash mixture if it is planned to merely boil the mash and not pressure cook it.

If the more energy efficient pressure cooking method is used, no enzymes need be added until the mixture has cooled to 190 degrees F. Then, add 1.5 ounces of alpha amylase per 100 pounds of corn and hold at 190 degrees F. for 30 minutes. If the boiling method is used, an additional 1.5 ounces of alpha amylase should be added to the mixture after it has cooled to 190 degrees F.

After maintaining the temperature at 190 degrees F. for approximately 30 minutes for either the boiling or pressure cooking method, the mixture should then be cooled to 140 degrees F. This can be done, at least partially, by adding water. At this point, the pH should be adjusted to 4.0, and 4.2 ounces of gluco amylase should be added. The mash mixture should then be held at 140 degrees F. for 30 minutes.

By this time, most of the starch in the mixture should be converted to free sugar. It is, at this point, necessary to test for sugar and remaining starch content in the solution. The sugar content can be measured with a Brix hydrometer, simply by filling a test tube with the solution and placing the hydrometer in the tube with the large end down. The contact point between the upper level of the solution and the hydrometer will produce a reading indicating the percentage of sugar in the mixture. Ideally, the mixture

should have around 15 percent sugar. If the sugar content is over 20 percent, the yeast cells die. Simply adding water to the solution can bring the sugar content down to the recommended 15 percent.

The remaining starch content in the mixture can be determined by placing a few drops of iodine in a beaker of mash. If the mash mixture turns purple, there is still unconverted starch in the mixture. The deeper purple the mixture turns, the more unconverted starch there is present. Allowing a little more retention time for the mash at 140 degrees F. will probably take care of the unconverted starch.

Fermentation

The mash mixture should then be cooled to below 90 degrees F. If the sugar content in the solution is 20 percent or greater, cool water can be added to dilute the sugar level to 15 percent and at the same time aid in cooling the mixture. When the temperature in the mixture has reached the 80 degree to 90 degree range, brewer's yeast should be added, in an amount equal to approximately .5 to 1 percent of the dry weight of the substrate used to make the mash (Example: 100 lbs. of corn x 1 percent = 1 lb. per 100 lbs. of corn x .5 percent = ½ lb.) This will start the fermentation process. After having gone through this process a few times, it may be determined that less yeast can be used. The pH level should still be between 4.0 and 4.5, but should be tested before adding yeast. A quart or two of the mash mixture can be used to mix with the yeast before introducing it into the rest of the mixture. As the yeast is introduced into the mixture, stir gently. This will mix the

yeast into the mash and supply oxygen to promote the initial propagation of the yeast. However, it should be emphasized that the mash should never be over stirred, as it will promote the production of acetic acid and detract from alcohol production. Gently stirring a few times each day will bring the yeast, which are not highly mobile, fresh food to transform into alcohol.

The three primary products of the fermentation process are new yeast cells, alcohol, and carbon dioxide. The formation of carbon dioxide bubbles in the mash can be used as a gauge to determine how well the first two are proceeding. The carbon dioxide should be vented into the atmosphere or stored and used for other purposes.

After the mash has worked about 40 hours, there will be a noticable slowing in the production of carbon dioxide bubbles. This should be an indication that the fermentation process is almost complete. Typically, a 48 - hour fermentation period is required by the yeast to convert the sugar in the mash mixture to alcohol. If the carbon dioxide bubbling s l o w s prematurely, a pH and temperature check should be made to make sure a pH of between 4.0 and 4.5 and a temperature of between 80 degrees F. and 90 degrees F. is still present in the mash. If so, the mash is probably deficient in a few nutrients, such as nitrogen, phosphorus or potassium. This usually will not happen if grain such as corn or wheat is used as a raw material. However, if it does happen, these nutrients should be added. A common source of nutrients essential for healthy yeast cultures is malted barley. The barley will not only supply the needed nutrients, but will also provide additional enzymes that may be needed.

A 15 percent sugar solution can be converted by brewer's yeast into an 8 to 12 percent alcohol solution. Often, in fermenting a sugar solution, the

yeast will die from alcohol poisoning before all the sugar has been consumed. It would, therefore, be beneficial to test the solution before and after distillation to determine the amount of sugar present and the potential for refermenting the solution after distillation or its use as a feedstuff. However, if care is used to keep the sugar level in the solution below 20 percent, and brewer's yeast is used instead of another variety such as baker's yeast, the alcohol production should end in close approximation with the consumption of the sugar in the solution.

After the fermentation splution has worked for approximatly 48 hours and carbon dioxide bubbling has almost ceased, the solution should be checked for alcohol content with a proof hydrometer. If the reading is satisfactory to indicate the fermentation process has been successfully completed, the solution can be separated with a centrifuge or other separation device sufficient to remove large particles while allowing the alcohol solution to pass through. These particles will contain approximately three times the percent of protein as the original feed stock. In addition, unused starch, dextrins, vitamins , and fats will be contained in the residue. This residue is called Distillers Wet Grains (DWG), or Distillers Dried Grains (DDG), when the material has been dried. This material makes an excellent feed for cattle or swine, and has potential for being processed into poultry feed as well as other types of animal feed.

After the grain has been removed from the fermentation solution, the solution will be ready for distillation. In fact, the Distillers Grain can be left in the solution while the distillation process is taking place, if the distillation system used is designed to accommodate them. Higher yields of alcohol are reported when leaving the DWG in the mixture until after distillation.

Distillation

Although there are many different designs for alcohol producing stills, they all operate on the same set of principles. One key definition to remember is that of distillation. Distillation is the separation, splitting apart or isolating of two or more compounds by vaporizing them. In the case of an alcohol and water mixture, such as fermented beer, distillation can be used because the two liquids have different boiling points. That is, water boils at 212 degrees F. and alcohol boils at 173 degrees F. A mixture of alcohol and water boil at varying temperatures between 212 degrees F. and 173 degrees F., depending on the ratio of the liquids in the mixture.

If the solution of 15 percent alcohol and 85 percent water is heated to a boil in an open container, the vapors given off by the solution will contain a larger amount of alcohol than water. As this happens, the percent of alcohol in the pan will decrease. Continuation of this process will cause the percentage of alcohol in the vapors to drop because of the lower alcohol concentrations in the pan. From this, it can be seen that as the distillation process begins, a higher proof alcohol will be produced than that produced near the end of the distillation process.

An average distillation run using a simple cooker and condenser will produce 80 to 140 proof alcohol. This alcohol will not be of a quality sufficient for motor vehicle use. Therefore, additional sophistication must be added to the distilling system in order to increase the proof. Moonshiners have used additional pots and condensers, distilling the product of the first still a second or third time, in an effort to increase the proof of their product. While this technique works fairly well, it is extremely energy intensive and will wind up using many times the energy contained in the final product.

A more efficient system for vaporizing, condensing and revaporizing the mixture is to use what is known as a pipe column. Such a still can be designed for continuous operation and continuous high proof production without a declining alcohol concentration toward the end of the run. The "perforated column" is a typical, fairly efficient and simple - to-construct pipe column still. However, a steady state of operation must be maintained with a constant minimum pressure or the liquid will dump through to the bottom of the column and out the spent mash drain. At proper temperature and pressure, the vapors will flow through holes in the plates and be cooled, thus causing water to condense and flow back down the column through the downcomer pipes, while the alcohol-enriched vapors continue upward.

Construction of a system such as this, capable of producing 20 gallons of 180 - 190 proof ethanol per hour should begin with two pieces of thin wall tubing approximately 12 inches in diameter and 16 feet in length. Next, 18 metal plates the same diameter as the inside of the tubing should be constructed from 1/8 inch metal. These plates should have between 50 and 57 holes, one-half inch in diameter, drilled in them. This will give them a ratio of between eight and ten percent of the surface area of the plates. These plates should be evenly spaced throughout the inside of the 16-foot pipe. Each plate should also be equipped with a 1¼ inch downcomer that extends 1¼ inch above the plate. This downcomer should extend downward to within 3/4 inch of the the next plate and have a two inch seal cup at the bottom. This downcomer forms a safety bypass for steam and beer vapor, in case the holes in the plate become plugged. The seal cup forms a liquid seal to keep the heated vapor from using the path of least resistance. The downcomer also acts as a downward flow passage for condensed liquid (which would be mostly water).

For the second 16 foot pipe, 24 plates 1/8 inch thick and the diameter of the inside of the pipe should have 490 to 520 holes, with a diameter of 5/32 inch. The plate should be evenly spaced in the column and have a 1¼ inch downcomer that extends 1¼ inch above the plate and downward to within 3/4 inch of the next plate and have a two inch seal cup at the bottom.

From the top of the column, a four inch thin wall tube should lead to the bottom of the second column. The first column (stripper column) should be equipped with a port at the bottom large enough for cleaning out any residue that will accumulate in the column. Temperature and pressure gauges should be located at the top, mid point and bottom of each column. The second column (rectifier column) should be equipped with a reflux line to return a part of the vaporous material from near the top of the column to the bottom for redistilling. This will increase the proof of the final product.

Both columns should be equipped with 15 PSI safety valves. If the source of heat used to distill the alcohol is steam, the boiler should also be fitted with appropriate safety valves. The steam should enter the bottom of the stripper column in a heat exchanger at approximately 15 PSI. The temperature near the bottom of the column should, consequently, be between 215 degrees F. and 220 degrees F. The mid point temperature of this column should be around 212 degrees F., while the temperature gauge near the top should read 195 degrees F. The temperature reading on the rectifier column should vary from around 190 degrees F. at the bottom to 173 degrees F. at the top.

The beer feed pipe can be used to operate a primary condenser from the vaporous product coming from the rectifier column. A temperature gauge on the product line is needed to indicate how much of the product may be escaping as vapor. The product should be cooled to between 60 degrees F. and 100 degrees F.,

but for best results should be as close to 60 degrees F. as possible.

The alcohol concentration in the condensed product should be checked frequently to assure things are working well. Alcohol concentrations of 190 proof or better should be obtained if the system is working properly.

If the temperature in the column gets too high, it can be lowered by increasing the beer feed rate. This will also have the effect of supplying more beer to the primary condenser to cool alcohol vapors.

MODIFYING AN AUTOMOBILE ENGINE TO USE ETHANOL

Alcohol has been used for a number of years as a motor fuel. In fact, it has been successfully used longer than gasoline. The Otto cycle, the first practical internal combustion engine, developed by Nikolaus Otto in 1877, ran on alcohol. Automobiles have run on alcohol at various times in our history, ever since that time. Manufacturers have offered vehicles with optional gasoline or alcohol fuel systems in the past.

Alcohol is an excellent fuel for at least three reasons. The first is its high octane rating (approximately 106), which helps prevent premature detonation (engine knock) under load. The second reason is that it burns cleaner than gasoline and helps prevent gum and varnish build-up in the engine. Finally, alcohol-powered engines run cooler than gasoline engines, which extends engine life.

The octane number given automotive fuels is an indication of the fuel's ability to resist premature detonation within the combustion chamber. Premature detonation comes about when the fuel-air mixture ignites spontaneously

because of intense heat and pressure within the compression chamber. Ideally, the fuel would not detonate until the piston reached the proper place for the ignition system to ignite the fuel. Even though gasoline engines typically have a lower compression ratio today than they did ten years ago, detonation is a greater problem now than it was then. This has been caused primarily by the reduced octane level of today's gasoline.

A high compression ratio in an engine results in more power per stroke, greater efficiency and better economy. Therefore, a fuel that resists premature detonation under high compression is desirable. On the average, alcohol is 16 points higher on the research octane scale than regular gasoline. This higher octane rating is generally cited as the reason most engines perform better with alcohol-gasoline blends or with straight alcohol, after the motor has been properly converted.

Alcohol's lower Btu level actually helps an engine run some 20 degrees F. to 40 degrees F. cooler than the same engine on gasoline.

Running an engine on alcohol fuel also has beneficial effects on the environment. Tests have shown that alcohol powered vehicles emit 95 percent less carbon monoxide and 87.5 percent less hydrocarbons.

While it is not necessary to have pure alcohol to power a vehicle, alcohol that contains more than 20 percent water will probably cause engine hesitation and rough idling. Alcohol requires a richer air/fuel ratio than gasoline. This richer mixture is not proportional with respect to increased fuel consumption. This is due, at least partially, to alcohol's higher octane rating. Also, because of the higher octane rating, an alcohol powered vehicle can maintain its fuel economy under loaded vehicle conditions better than its gasoline counterpart.

The method typically used to produce the richer fuel-to-air ratio is to increase carburetor jet orifice size. The main metering jet orifice is one of the first things which must be changed. This orifice's size and regulation determine how rich or lean the air/fuel ratio will be when operating a vehicle under cruising conditions. Typically, an enlargement of this orifice area by 23 to 28 percent will be sufficient to enrich the fuel /air ratio enough to allow the engine to run successfully on alcohol. However, several different jet orifice sizings may need to be tried before setting on the best orifice size for a particular automobile. An auto repair manual will be a handy tool to have while attempting this and other changes necessary for successful alcohol fuel conversion. After the conversion has been complete , be sure to periodically check spark plugs for accumulation of white ash. This is an indication that the fuel/air mixture is too lean and is causing the engine to run hot.

The second change needed in the motor's carburetion system is the idle jet orifice size. This jet controls carburetion at low and idle speeds and will probably also have to be enlarged to accommodate alcohol fuels. In some engines, merely backing the idle screw adjustment out will allow enough alcohol into the engine for proper idling. However, if this is not possible, the idle jet orifice should be bored out to approximately 25 - 40 percent greater area than it occupies while using gasoline.

If the motor being converted has a power valve in its carburetor, this valve should also be enlarged to accommodate the additional alcohol needed to provide a richer fuel/air mixture under accelerating conditions. Usually, an increase of approximately 25 percent by area for this valve will satisfy the conversion requirements.

The acceleration pump on most motors will need to be altered in order to provide for the very rich fuel/air mixture needed for starting and initial acceleration. Some accelerator pumps are equipped with adjustable operating rods. For converting this type of accelerator pump, merely lengthening the stroke of the operating rod will usually be sufficient. Other accelerator pumps may have to be replaced with pumps of a larger capacity.

Alcohol fuel's higher octane rating gives it the ability to withstand increases of ignition beyond that of gasoline without fear of premature detonation. Therefore, in the process of converting an engine from gasoline to alcohol, the ignition timing can be advanced between 5 degrees and 12 degrees further than it could be while running on gasoline. This will improve vehicle performance and not damage the engine due to premature detonation.

The higher octane rating of alcohol fuel can only be taken full advantage of if the engine being converted has a higher compression ratio. Because most modern engines have a compression ratio of between 8 to 1 and 8.5 to 1, they will never realize the full performance potential of alcohol fuels. However, certain steps can be taken to increase compression ratio. The pistons in the engine can be replaced with high-compression pistons, which sit higher in the cylinder than regular pistons. This change may need to be accompanied by changing rods and bearings with their high performance counterparts in order to avoid engine damage.

Another way to increase the engine's compression ratio is with the addition of a turbo-charger. This device will pack the air/fuel mixture into the cylinders thus increasing the compression ratio. Maximum compression increases would come at peak RPM conditions and therefore would not cause problems with starting.

When an engine is initially altered to use alcohol fuel, certain problems may occur. First, alcohol is a solvent and will tend to loosen and remove the gum and varnish that has accumulated in an engine's fuel system. This gum and varnish will tend to make its way through fuel lines to the engine fuel filters. These filters may become plugged either partially or completly during the first tank or two of alcohol fuel. Therefore, preparation should be made in advance to replace these filters. Many vehicles will have two fuel filters. The first will be a fiber filter on the fuel line just before it reaches the carburetor. The second filter is usually located inside the carburetor at the point where the fuel line connects to the carburetor.

GLOSSARY

ALCOHOL - a class of organic chemicals composed of carbon, hydrogen, and oxygen which include methanol, ethanol, and other alcohols; most alcohols will burn when ignited in air.

ANHYDROUS - means "without water." The ethanol contained in gasohol is usually anhydrous; even small amounts of water in ethanol may cause separation of the alcohol - gasoline.

AFT (Bureau of Alcohol, Tobacco, and Firearms) - the federal agency responsible for the licensing and regulation of alcohol production and sales.

DESTRUCTIVE DISTILLATION - a process where organic wastes high in cellulose content, such as wood in forest residue, are heated in the absence of oxygen to burn the wastes and then separate the methanol.

DISTILLER'S DRIED GRAINS (DDG) and DISTILLER'S WET GRAINS (DWG) - a high protein by-product of the grain fermentation process which is used as an animal feed.

FERMENTATION- the process whereby starches and sugars contained in crops are broken down by bacteria and yeasts to produce alcohols.

GASOHOL - a registered trademark held by the State of Nebraska for a fuel mixture of 10 percent anhydrous ethanol and 90 percent unleaded gasoline; it is often used to mean any mixture of alcohol and gasoline to be used as a fuel.

LEAN FUEL MIXTURE - an excess of air in the air/fuel ratio.

OCTANE NUMBER - a measure of a fuel's tendency to resist detonation (pinging) in a spark ignition engine.

PROOF - a measure of ethanol volume in a liquid at 60°F. The ethanol proof number is twice the percentage number. Anhydrous ethanol used in gasohol is usually 200 proof, or 100 percent alcohol.

RICH FUEL MIXTURE - an excess of fuel in the air/fuel ratio.

SACCHARIFICATION - converting carbohydrates into sugar.

INSTRUCTIONAL MATERIALS

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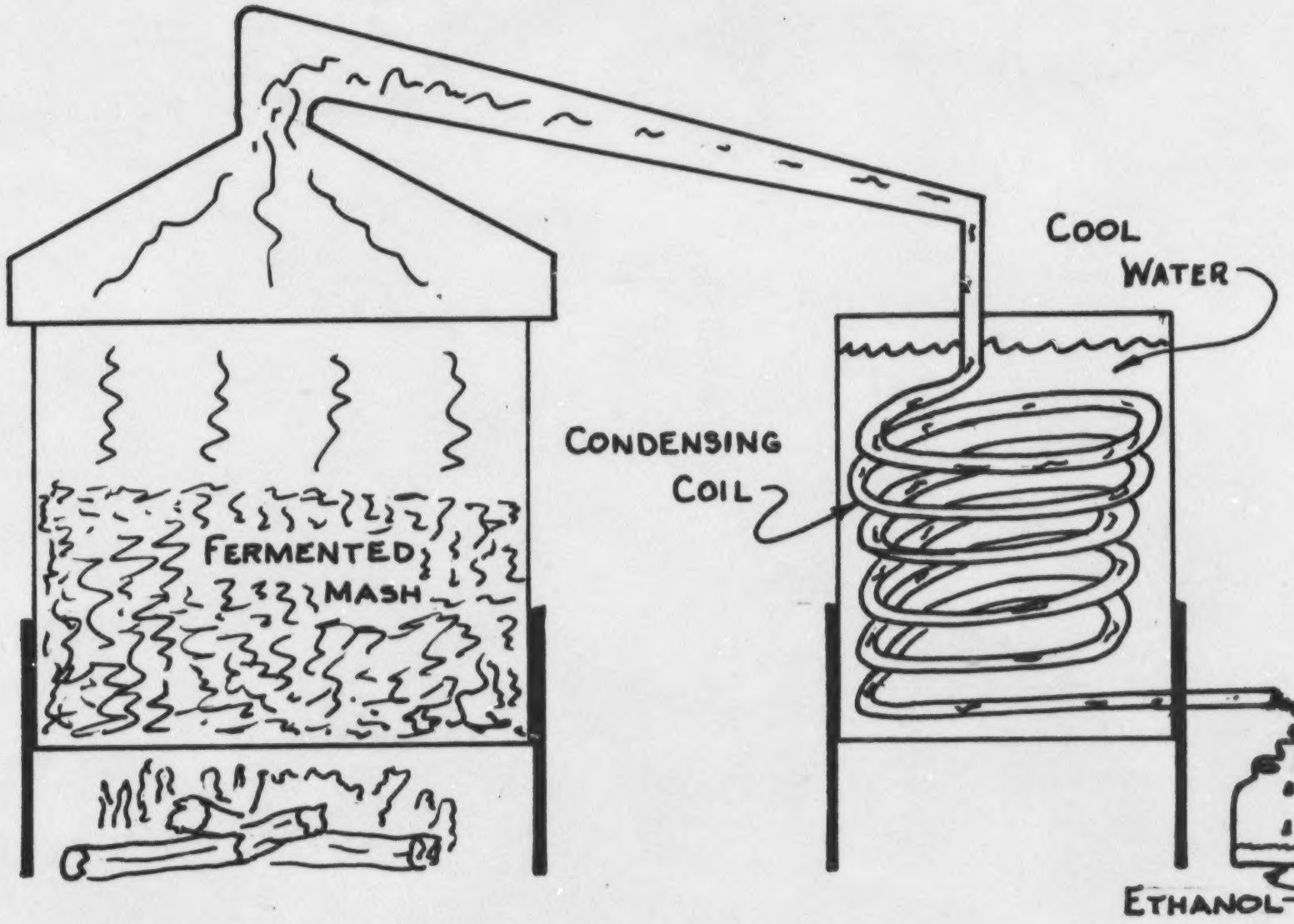
A. Pot Still

B. A Simple Process Diagram

II. SUGGESTED ACTIVITIES

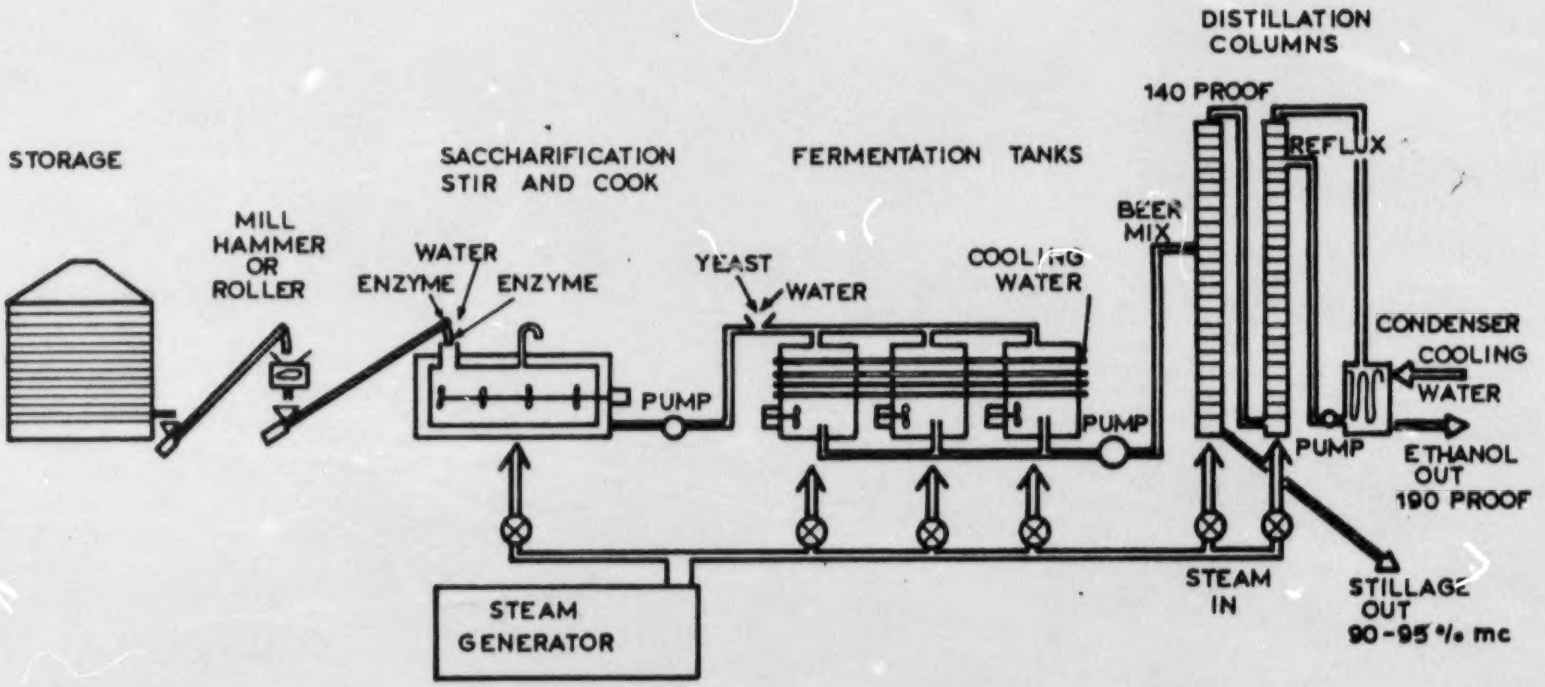
III. LECTURE OUTLINE

IV. BIBLIOGRAPHY



POT STILL

A SIMPLE PROCESS DIAGRAM



1 BU. CORN + 12-15 GAL. WATER + ENZYMES + HEAT + 10-15 GAL. WATER + YEAST + TEMP. CONTROL → DISTILLATION (HEAT) → ETHANOL + STILLAGE

REPRINTED FROM: "Production and Use of Ethanol"

SUGGESTED ACTIVITIES

Due to the tendency of students to misuse ethanol (they drink the stuff!), it is suggested that for classroom activities the teacher exercise careful control. You may substitute methanol (wood alcohol which is poisonous and cannot be consumed) for ethanol. Methanol is used in racing engines for safety and should be available through any local industrial chemical supply firm. Be sure to warn students that it is methanol you are using since it is very toxic.

A. Burn a small amount of methanol in an open dish to demonstrate the lower energy level.

B. Demonstrate the potential as a fuel by injecting a small amount into the venturi of a running lawn mower engine.

C. Modify a carburetor to "run" on alcohol by enlarging the jets by approximately 40%. Check this in advance since this may not be the correct amount for your test engine.

D. Assign students to verify the octane rating of a "gasohol" and an unleaded gasoline at the local service station.

LECTURE OUTLINE

I. INTRODUCTION

II. PROCESS FOR MAKING ETHANOL ALCOHOL FOR FUEL

1. When an individual decides to investigate making alcohol fuels, one of the first things that must be done is to determine what raw material will be used to make alcohol.

2. It is possible to make alcohol from almost any organic material.

3. Remember the federal government controls the manufacture and distribution of alcohol distillates.

4. There are three types of organic materials generally used to make alcohol: sugar, starch, and cellulose.

A. Mash Preparation

1. Preprocessing or grinding the chosen raw material is necessary to ready the material for efficient processing.

2. By raising the temperature of the mash to 250 degrees F. for 20 minutes, under 15 lbs. pressure, the mash mixture will be sterilized.

3. For each bushel of corn used, between 15 and 20 gallons of water should be added. This is less than the total needed for fermentation (27 to 28 gallons) but will require less energy for the cooking process.

4. Merely boiling the mash will not sterilize it and will require more energy than pressure cooking. A simple rule to follow is to make the starchy material soft. This can be accomplished by boiling the mash for 30 minutes or pressure cooking the mash.

B. Hydrolysis-Saccharification

1. Before cooking, the acid concentration of the mash should be adjusted to obtain a pH of between 6.0 and 6.5. If the mixture is base, the acid concentration can be adjusted by adding sulphuric or hydrochloric acid in dilute form.

2. The pH level in the mixture can be determined by the use of pH test paper.

3. Be careful to dilute the acid before putting it into the mash mixture and only use a little at a time.

4. If the more energy efficient pressure cooking method is used, no enzymes need to be added until the mixture has cooled to 190 degrees F. Then, add 1.5 ounces of alpha amylase per 100 pounds of corn and hold at 190 degrees F. for 30 minutes.

5. After maintaining the temperature at 190 degrees for approximately 30 minutes, the mixture should be cooled to 140 degrees. The pH should then be adjusted to 4.0 and 4.2 ounces of gluco amylase should be added. The mash mixture should then be held at 140 degrees for 30 minutes.

6. By this time, most of the starch in the mixture should be converted to free sugar. The sugar content can be measured with a Brix hydrometer.

7. The mixture should be around 15 percent sugar. If the sugar content is over 20 percent, the yeast will die. The mash mixture should be cooled to between 80 to 90 degrees. If the sugar content is too high, cool water can be added to reduce the sugar content and cool the mixture at the same time.

C. Fermentation

1. Brewer's yeast should be added in an amount equal to .5 to 1 percent of the dry weight of the substrate used in the mash. (Example: 100 lbs. of corn X 1% = 1 lb. of yeast.) This will start the fermentation process.

2. The pH level should still be between 4.0 and 4.5.

3. Gently stirring a few times each day will bring the yeast, which are not highly mobile, fresh food to transform into alcohol.

4. The three primary products of the fermentation process are new yeast cells, alcohol, and carbon dioxide. The formation of carbon dioxide bubbles in the mash can be used as a gauge to tell how well the first two are working.

5. After the mash has worked about 40 hours, there will be a noticeable slowing in the production of carbon dioxide bubbles. This indicates that the fermentation process is almost complete. Typically, a 48-hour fermentation process is required to enable the yeast to convert the sugar in the mash mixture to alcohol.

6. If the bubbling slows prematurely, check the pH and temperature to make sure they are between 4.0 and 4.5 and 80 to 90 degrees respectively.

7. A 15 percent sugar solution can be converted by brewer's yeast into an 8 to 12 percent alcohol solution.

8. Brewer's yeast should always be used instead of baker's yeast. Brewer's yeast will give higher levels of alcohol.

9. After the grain has been removed from the fermentation solution, the solution will be ready for distillation.

D. Distillation

1. Distillation is the separation of two or more compounds by vaporizing one of them and not the other.

2. In the case of an alcohol and water mixture, such as fermented beer, distillation can be used to boil off the alcohol. Water boils at 212 degrees and alcohol boils at 173 degrees. If the mixture is heated to between these two temperatures, the alcohol will boil off, leaving the water.

3. The alcohol vapor is then caught and condensed.

4. As the distillation process begins, a higher proof alcohol will be produced and a lower proof alcohol will be produced near the end.

5. An average distillation run using a pot still will produce 140 to 80 proof alcohol. This alcohol will not be of a quality sufficient for motor vehicle use.

6. A more efficient system of vaporizing, condensing and revaporizing the mixture is to use what is known as a pipe column. Such a still can be designed to continuously operate and produce a constant high proof alcohol.

7. The perforated plate column is a typical, fairly efficient and simple to construct pipe column still. However, this type of still must operate constantly or the liquid will dump out.

8. Construction of a system such as this is capable of producing 20 gallons of 180-190 proof ethanol per hour.

III. MODIFYING AN AUTOMOBILE ENGINE TO USE ETHANOL

1. The Otto cycle, the first practical internal combustion engine, developed by Nikolaus Otto in 1877, ran on alcohol.

2. Automobiles have run on alcohol at various times in our history.

3. Alcohol is an excellent fuel for three reasons:

   a. The first reason is its high octane rating (approximately 160), which helps prevent premature detonation (engine knock) under load.

   b. The second reason is that it burns cleaner than gasoline and helps prevent gum and varnish build-up in the engine.

   c. Finally, alcohol powered engines run cooler than gasoline engines, which extends engine life.

4. Alcohol requires a richer air/fuel ratio than gasoline.

5. The method typically used to produce the richer fuel to air ratio is to increase carburetor jet orifice size. Typically, an enlargement of this orifice area by 23 to 28 percent will sufficiently enrich the fuel-air ratio to allow the engine to run successfully on alcohol.

6. The second change needed in the motor's carburetion system is the idle jet orifice size. This jet controls the low and idle speeds and will probably have to be enlarged by approximately 25 to 40 percent greater area.

7. If the motor being converted has a power valve in its carburetor, this valve should also be enlarged to accommodate the additional alcohol needed to provide a richer fuel/air mixture under acceleration conditions. Usually an increase of 25 percent will suffice.

8. The accelerator pumps on most motors will need to be altered in order to provide for the very rich fuel/air mixtures needed for starting.

9. In the process of converting an engine from gasoline to alcohol, the ignition timing can be advanced between 5 percent to 12 percent further than it can while running on gasoline.

10. The pistons in the engine can be replaced with high compression pistons which sit higher in the cylinder than regular pistons. This change may need to be accompanied by changing rods and bearings with their high performance counterparts.

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ALCOHOL FUELS STUDENT STUDY SHEET

1. When did the Arabs have the 1st oil embargo?
2. Which major country is in the process of converting all its cars from gasoline into alcohol?
3. What is the purpose of pH test paper?
4. How many gallons of water are needed for the fermentation of one bushel of corn?
5. What are the primary products of the fermentation process?
6. What type of yeast should be used in the fermentation process?
7. What will be the net effect of a 15 percent sugar solution as far as <u>percent</u> alcohol solution?
8. What is the definition of "Distillation"?
9. What are the boiling points of alcohol and water?
10. What proof alcohol will an average distillation run produce using a simple cooker condenser?
11. Name two principle advantages of a pipe column distillery.
12. How long has alcohol been used as a fuel for motor vehicles?
13. What was the "Otto Cycle"?
14. Why is alcohol an excellent fuel?
15. What does the "octane number" mean?
16. Does alcohol require a richer fuel-air mixture than gasoline?
17. Name three advantages of using alcohol as a fuel in your motor car.
18. Why should you change the fuel filter when you change over from gasoline to gasohol or alcohol?
19. What are some of the necessary engine modifications that must be made before you change from gasoline to alcohol as the fuel in your car?

ASSIGNMENT NO. 1

1. Give a short explanation of the fermentation process necessary to make alcohol fuels.

ASSIGNMENT NO. 2

1. Describe and explain the distillation process of a pipe column.

ASSIGNMENT NO. 3

1. List the eight (8) necessary modifications to convert an engine from burning gasoline to the use of alcohol.

ASSIGNMENT NO. 1

1. Give a short explanation of the fermentation process necessary to make alcohol fuels.

With the addition of brewer's yeast to a sterilized mixture of one bushel of corn meal and 28 gallons of water at 90 degrees F., the fermentation process will begin. The yeast should be added at the rate of ½ to 1 lb. per 100 lbs. of corn.

The mixture should be gently stirred a few times each day.

After the mash has worked about 40 hours there will be a noticable decline in the production of carbon dioxide bubbles in the mash. Typically, a 48 hour fermentation period is required for the yeast to convert the sugar in the mash mixture to alcohol. The mixture can be checked for alcohol content by the use of a proof hydrometer.

ASSIGNMENT NO. 2

1. Describe and explain the distillation process of a pipe column.

The "pipe column" distillery is a design for continuous operation and continuous high proof production without a declining alcohol concentration toward the end of the run. The perforated plate column is a typical and fairly efficient and simple to construct pipe column still.

At the proper temperature and pressure, the vapors from the heated beer will flow through holes in the plates and be cooled, thus causing water to condense and flow back down the column while alcohol enriched vapors continue upward.

Construction of such a system as this is capable of producing 20 gallons of 180-190 proof ethanol per hour.

ASSIGNMENT NO. 3

1. List eight (8) necessary modifications to convert an engine from burning gasoline to the use of alcohol.

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1. Increase the carburetor jet orifice by 23 to 28 percent.
2. The engine's idle jet should be either backed off or bored out to approximately 25 to 40 percent greater area for proper idling.
3. The power valve should be enlarged by 25 percent.
4. A larger capacity accelerator pump should be installed.
5. The engine timing should be advanced between 5 to 12 degrees.
6. The engine's pistons should be replaced with high compression pistons to raise the compression ratio.
7. The rods and bearings should be replaced with their high performance counterparts.
8. The addition of a turbo-charger for an increased compression ratio.

ALCOHOL FUELS

TEST

NAME _____

DATE _____

GRADE _____

_____ 1. _____ is the major South American country which is involved in conversion from gasoline powered vehicals to alcohol powered vehicles.

a. Gianna
b. Panama
c. Brazil
d. Columbia

_____ 2. It takes _____ to _____ gallons of water per bushel of corn to complete the fermentation process.

a. 4-12
b. 13-19
c. 27-28
d. 39-51

_____ 3. Sugar content in the starch mixture of the fermentation solution can be measured by _____.

a. Thermometer
b. Brix hydrometer
c. pH test paper
d. None of the above.

_____ 4. Brewer's yeast should be added to the mash mixture at a rate of _____ per 100 lb of corn.

a. 2 ounces
b. ½ lb
c. 1 lb
d. 2 lb.

_____ 5. Typically, a _____ hr fermentation period is required by the yeast to convert the sugar in the mash mixture to alcohol.

a. 24
b. 36
c. 48
d. 60

____ 6. A 15 percent sugar solution can be converted by brewer's yeast into an ____ to ____ percent alcohol solution.

a. 8 - 12
b. 12 - 15
c. 15 - 19
d. None of the above.

____ 7. The material which is the result of the fermentation process contains approximately 3 times the percentage of protein as the original feed stock. This material is called _____.

a. Sawdust
b. Distillers Wet Grains
c. Corn Meal
d. None of the above.

____ 8. Construction of a pipe column distillery is capable of producing _____ gallons of 180 to 190 proof alcohol per _____.

a. 20 - hr
b. 20 - day
c. 10 - hr
d. None of the above.

____ 9. The first practical internal combustion engine ran on _____.

a. gasoline
b. diesel
c. kerosine
d. alcohol

____ 10. Alcohol burns _____ than gasoline.

a. cleaner
b. slower
c. faster
d dirtier

LISTING

1. Name three substances that would yield a high level of alcohol if they were used as the substrate.

   a.
   b.
   c.

2. List 3 advantages of the use of alcohol fuels.

   a.
   b.
   c.

3. List at least 3 modifications necessary to convert an engine from gasoline to alcohol.

   a.
   b.
   c.

ALCOHOL FUELS

TEST ANSWERS

Multipe Choice

1. C
2. C
3. B
4. B or C
5. C
6. A
7. B
8. A
9. D
10. A

Listing

1. Name 3 substances that would yield a high level of alcohol if they were used as the substrate.
   a. Corn
   b. Wheat
   c. Rice

2. List 3 advantages of the use of alcohol fuels.
   a. Higher octane for "no knock" performance.
   b. Cleaner burning
   c. Extended engine life

3. List 3 modifications necessary to convert an engine from gasoline to alcohol.
   a. Carburetor adjustments
   b. Replacement of regular pistons with high performance pistons.
   c. Replacement of fuel filters regularly.

Dear Teacher:

The evaluation of the completed materials is a critical step in the curriculum development process. It is required that all recipients of the materials prepared by the Alternative Energy Curriculum Project furnish such an evaluation. After you have had time to review this learning packet, complete this questionnaire and return it to the Arkansas Research Coordinating Unit.

This evaluation is for: (Check (✓) one)

( ) Alcohol Fuels ( ) Nuclear Energy ( ) Wind Power

( ) Conservation ( ) Solar Energy

Evaluate each section of the learning packet by placing a check (✓) in the Favorable or Unfavorable column. If the evaluation is Unfavorable, please state the reason in the space beside the section name.

Favorable	Unfavorable		
( )	( )	Information Section	_____
( )	( )	Instructional Materials	_____
( )	( )	Student Study/Assignment Sheets	_____
( )	( )	Tests	_____

Evaluate the following characteristics of the learning packets by placing a check (✓) in the appropriate response.

Readability: ( ) Too High ( ) Too Low ( ) Right Grade Level

Material Length: ( ) Too Long ( ) Too Short ( ) Correct Length

Technical Level: ( ) Too Technical ( ) Too General ( ) Right Technical Level

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Do you plan to use this material in your classes? Check (✓) Will or Will Not. If Will, supply requested information. If Will Not, state reasons.

( ) Will

Name of Class _____

Grade Level of Class _____

School Name _____

( ) Will Not

Reasons _____

If additional Alternative Energy Curriculum materials would be of use in your classes, check (✓) those energy topics which should be developed.

( ) Bio-Mass ( ) Fuel Cells ( ) Methane ( ) Coal ( ) Geothermal

( ) Other _____

Thank you for your evaluation. Fold this questionnaire so the return address is on the outside. Seal with a small piece of tape. Place a first class stamp in the upper right hand corner and mail.

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IMPORTANT !!!

EVALUATION QUESTIONNAIRE

Place
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Education Building West, Room 305-D
Arkansas Department of Education
Little Rock, Arkansas 72201

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